Renewable and Sustainable Energy Reviews 14 (2010) 1048–1058

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Productivity and development issues of global wind turbine industry

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ARTICLE INFO

Article history:
Received 21 October 2009
Accepted 27 October 2009

Keywords:
Wind
Energy
Turbine
Global
Development
Employment

ABSTRACT

The use of wind energy reduces CO_2 emission and increases new employment opportunities. The positive impacts of wind energy on the mitigation of climate change as well as opportunity to diminish energy dependency are indisputable. Wind energy helps decreasing import dependency, diversifying sources of production, and contributes to a sustainable development in many countries. This article explores the importance of global wind turbine development and other relevant issues which are important. In this energy scenario, global installed wind turbines, energy potential and employment issues were discussed. Wind energy deployment creates a significant number of jobs, and does so at a time when other energy sectors are shrinking. Global wind turbine installation for recent years (2006–2008) was thoroughly discussed along with employment issues regarding wind industry in the world. The wind energy sector has grown exponentially since the end of the 1990s, especially within many countries, and this has affected the employment levels of countries involved.

Contents

1. Introduction

Renewable energies (REs) represent a cornerstone to steer our energy system in the direction of sustainability and supply security

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1364-0321/$ – see front matter
doi:10.1016/j.rser.2009.10.031

and a broad set of different RE technologies and resources exist today [1]. Wind is one of the world's fastest-growing renewable energy sources. The rapid growth in wind power is a result of improvements accomplished in technology [2]. The recent focus on finding solutions for mitigating global warming has resulted in renewable energy technologies gaining importance. Among the renewable energy technologies, wind power is one of the fastest-growing technologies globally at an average annual growth rate of more than 26% since 1990 [3,4].

The worldwide demand for renewable energy is increasing rapidly because of the climate problem, and also because oil resources are limited. Wind energy appears as a clean and good solution to cope with a great part of this energy demand [5]. Developing a utility-scale wind project is a complicated and time-consuming process involving developers, landowners, utilities, the public and various local authorities. Although each wind energy project is unique and have different characteristics, basic features and related steps are common [2]. In practice, the steps are iterative and overlap one another depending on the specific project circumstances. The key steps of development and planning for a wind farm are site selection, detailed wind assessment, feasibility, construction and operation [2,6].

Estimates of the global technical potential of solar energy range from 15 to 4300 EJ, and for on-shore wind 3–600 EJ [7–9]. Over three quarters of global wind turbine sales come from only four turbine manufacturing companies: Vestas, GE Wind, Enercon, and Gamesa [10].

The Intergovernmental Panel on Climate Change (IPCC) in 2001 [11], for example, estimated the annual global theoretical terrestrial potential of wind as 1728 EJ from all land with mean annual wind speeds >5.1 m/s at 10 m above the ground. This amount was then reduced to give a technical potential of only 72 EJ based on the experience of the Netherlands and the USA [7]. As a resource, wind energy offers a number of advantages over solar energy. Peak energy intensity for wind turbines is currently around 400 W/m^2, more than twice that for solar PV [7].

Energy is one of the essential inputs for economic development and industrialization. Fossil fuels are the main resources and play a crucial role to supply world energy demand. However fossil fuel reserves are limited and usage of fossil fuel sources have negative environmental impacts. Therefore, management of energy sources, rational utilization of energy, and renewable energy source usage are vital. Since the first oil crisis, renewable energy sources have gained a great importance due to their inexhaustibility, sustainability, ecological awareness and supply of energy security. So, renewable energy sources are expected to play an important role especially in electrical energy generation [12].

Among the renewable energy sources wind energy is currently viewed as one of the most significant, fastest growing, commonly used and commercially attractive source to generate electrical energy because of the mature and cost effective energy conversation system technology. So, electricity generation cost from wind energy system has become competitive with fossil fuel systems. Installed total wind power capacity has reached over 93 GW and installed wind power capacity generates more than 1% of the global electricity consumption. In recent years Weibull distribution has been one of the most commonly used, accepted, recommended distribution to determine wind energy potential and it is also used as a reference distribution for commercial wind energy softwares such as Wind Atlas Analysis and Application Program (WAsP) [12–15]. Germany is a leader in Europe on shifting from conventional to renewable sources of energy. As its land-based sites of wind energy are built to capacity [16,17], Germany looks to the sea for further production possibilities. In the United States and Germany, offshore areas are generally considered public space, which makes offshore renewable energy development public in nature [18].

Many countries and sub-national governments are looking not only to expand their domestic use of renewable energy, but also to develop accompanying local renewable energy technology manufacturing industries to serve that demand [18]. Cost is a central issue in meeting greenhouse gas emission reduction goals [19,20]. Some clean energy technologies are relatively costly today but costs may decrease over time as technological improvements occur, equipment is standardized, and economies of scale take hold [20].

Electricity generated from wind power currently represents only 0.5% of global electricity production, and about a 7 billion (US) dollar annual industry [23]. The market is expected to double over the next 4 years [10], and it is this perceived potential for future growth and the rapid growth rates to date that are causing many governments to look toward developing domestic wind technology manufacturing industries. Countries and sub-national governments around the world—in both developed and developing countries—are therefore establishing policies to promote the construction of new wind power installations, and some have developed targeted policies to specifically encourage local manufacturing of large wind turbine technology [25]. The reasons why it is difficult to quantify the exact number of jobs coming from wind-related activities have to do with the lack of detail in the official statistics, which does not allow researchers to exploit the data, and with the variety of company profiles that make up the sector, which can be hard to identify and examine. The wind energy sector has grown exponentially since the end of the 1990s, especially within the European Union (EU), and this has affected the employment levels of the regions involved [26].

2. Global installed wind turbines and energy potential

A reliable supply of energy is essential to maintain and to improve human being's living conditions. Compared to the conventional coal-fired approach, renewable energy (RE) helps to mitigate the impacts of greenhouse gas emissions to a large extent. According to the Global Wind Energy Council (GWEC), the global cumulative installed capacity has reached 94 GW in 2007, which increased 31% than the previous year [24,27]. Today, the world's energy supply is largely based on fossil fuels and nuclear power. These sources of energy will not last forever and have proven to be contributors to our environmental problems. The environmental impacts of energy use are not new but they are increasingly well known; they range from deforestation to local and global pollution. In less than three centuries since the industrial revolution, mankind has already burned roughly half of the fossil fuels that accumulated under the earth's surface over hundreds of millions of years. Nuclear power is also based on a limited resource (uranium) and the use of nuclear power creates such incalculable risks that nuclear power plants cannot be insured [28].

Based on a survey among the World Wind Energy Association (WWEA) member associations, a double digit growth for the wind energy market is expected despite the general economic crisis. Based on available figures from 11 of the top 15 countries representing over 80% of the world market, WWEA recorded 5374 MW new installed capacity in the first quarter of 2009, equaling an increase of 23% compared with last year in the same countries. WWEA keeps its previous prevision of a total installed capacity of 152,000 MW worldwide by the end of 2009 (Fig. 1), which will mean a new record of over 30,000 MW newly installed capacity within one year. This represents a market growth of 25% compared with last year [29].

Based upon the World Wind Energy Report in 2008, following global highlights is important [30]:

- Worldwide capacity reaches 121,188 MW, out of which 27261 MW were added in 2008.

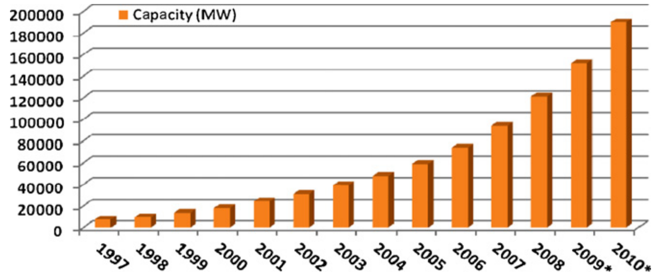


Fig. 1. Total world installed capacity [30].

Table 1
Technical and theoretical potentials and usage for various renewable energy sources (in terms of primary energy) at global scale [33].

Resource	Use in 2004 (EJ)	Technical potential	Theoretical potential
Biomass	50	250	2,900
Geothermal	2	5000	140,000,000
Hydropower	10	50	150
Ocean	–	–	7,400
Solar	0.2	1600	3,900,000
Wind	0.2	600	6,000
Total	62.4	7500	143,916,450

- Wind energy continued its growth in 2008 at an increased rate of 29%.
- All wind turbines installed by the end of 2008 worldwide are generating 260 TWh per annum, equaling more than 1.5% of the global electricity consumption.
- The wind sector became a global job generator and has created 440,000 jobs worldwide.
- The wind sector represented in 2008 a turnover of 40 billion Euros.
- For the first time in more than a decade, the USA took over the number one position from Germany in terms of total installations.
- China continues its role as the most dynamic wind market in the year 2008, more than doubling the installations for the third time in a row, with today more than 12 GW of wind turbines installed.
- North America and Asia catch up in terms of new installations with Europe which shows stagnation.
- Based on accelerated development and further improved policies, a global capacity of more than 1,500,000 MW is possible by the year 2020.

The status of wind energy is as a stable, profitable and low-risk investment. Although some wind energy projects are postponed due to financing challenges, the overall market development can still compensate such delays showing great signs of vitality. A substantial share of the slow down in some regions are a consequence of new regulations and bureaucratic delays that undermine the development of new wind parks rather than have financing difficulties [29].

Areas of potential wind turbine improvements include [21,22]:

- Advanced tower designs, including taller towers, new materials, and telescoping towers that are easier to install.
- Larger rotors made from lighter materials and having improved aerodynamics.
- More efficient gear boxes, drive trains, generators, and electronics.

Renewable sources of energy are essential parts of an overall strategy of sustainable development. They help reduce dependence of energy imports, thereby ensuring a sustainable supply. Furthermore renewable energy sources can help improve the competitiveness of industries over the long run and have a positive impact on regional development and employment. Renewable energy technologies are suitable for off-grid services, serving those in remote areas of the world without requiring expensive and complicated grid infrastructure [28].

2.1. Energy potential

The theoretical potential of wind energy as illustrated in Table 1 amounts to 6000 EJ (or more than 12 times current energy needs), what seems to be enormously high when compared to its current use. A technical potential is estimated to be 10% of the theoretical one. The ultimate potential of wind-generated electricity worldwide could indeed be very large: other assessments state figures of up to 50 times current global final electricity consumption [1,33–35].

Height limitations of wind converters, coast distance of offshore sites, insufficient wind velocities and land use, and the feasible grid integration all limit the realizable potential of this promising technology option.

2.1.1. Technical potential

If technical boundary conditions (i.e. efficiencies of conversion technologies, overall technical limitations as, e.g. the available land area to install wind turbines) are considered the technical potential can be derived.

2.1.2. Theoretical potential

For deriving the theoretical potential general physical parameters have to be taken into account (e.g. based on the determination of the energy flow resulting from a certain energy resource within the investigated region). It represents the upper limit of what can be produced from a certain energy resource from a theoretical point-of-view—of course, based on current scientific knowledge [1].

Potential for geothermal energy is higher than other resources of energy, but its use was only 2 EJ in 2004 which is very low.

Potential for biomass energy is 2900 EJ, but its use was 50 EJ in 2004 which was highest if we compare with other resources of energy in the world.

The top five countries in terms of total installed wind capacity at the end of 2004 were Germany, Spain, USA, Denmark, and India; wind turbine manufacturers from these top five countries sold 94% of all wind turbines installed globally in 2004. Germany clearly stands out as having maintained the most sizable and stable market [25].

The US and Indian markets have been much less stable than those of Germany, Spain, and Denmark. Annual installations in the US were highest in 2001 and 2003 with over 1600 MW installed each year. However, annual installations dipped well below 200 MW per year between 1995 and 1998, and again in 2000. The year 2004 was also slow in the US, as the on-again, off-again nature of the federal production tax credit (PTC) has created significant uncertainty in the market in recent years. India's market has also been unstable, with initial growth in the mid 1990s, a slowdown in the late 1990s, and some resurgence in recent years. From 2001 to 2004, however, India has been able to maintain annual installations of over 200 MW per year. Though the instability of the Indian and US markets has not stopped local investments in wind manufacturing (in part because the long-term market potential is so large in both countries), it has often complicated the process of developing successful local wind manufacturing industries [25].

The Brazilian government has also pursued policies governing wind farm development that include stringent local content

requirements, primarily through the recent Proinfa legislation (the Incentive Program for Alternative Electric Generation Sources) that offers fixed-price electricity purchase contracts to selected wind projects. Starting in January 2005, the Proinfa legislation requires 60% of the total cost of wind plant goods and services to be sourced in Brazil; only companies that can prove their ability to meet these targets can take part in the project selection process. In addition, from 2007 onwards, this percentage increases to 90% [25,31].

China has also been using local content requirements in a variety of policy forms. China's 1997 "Ride the Wind Program" established two Sino-foreign joint venture enterprises to domestically manufacture wind turbines; the turbines manufactured by these enterprises under technology transfer arrangements started with a 20% local content requirement and a goal of an increase to 80% as learning on the Chinese side progressed [25,32]. China's recent large government wind tenders, referred to as wind concessions, have a local content requirement that has been increased to 70% from an initial 50% requirement when the concession program began in 2003. Local content is also required to obtain approval of most other wind projects in the country, with the requirement recently increased from 40% to 70% [25].

3. Wind market growth rates

An important indicator for the vitality of the wind market is the growth rate in relation to the installed capacity of the previous year. The growth rate went up steadily since the year 2004, reaching 29.0% in 2008, after 26.6% in 2007, 25.6% in the year 2006 and 23.8% in 2005. However, this increase in the average growth rate is mainly due to the fact that the two biggest markets showed growth rates far above the average: USA 50% and China 107% (Fig. 2). Bulgaria showed the highest growth rate with 177%, however, starting from a low level. Also Australia, Poland, Turkey and Ireland showed a dynamic growth far above the average [30]. Fig. 3 shows that world wind market growth rate in 1999 was the highest and then was decreased to the year 2004 which was the lowest. Since 2004 it has had a slight increase. It is also interesting to know that growth rate for Turkey in 2007 was a lot more than 2008.

Between 1991 and 1995 both the average list price of wind turbines and turnkey investment costs of wind farms in Germany have declined steadily by about 8–9% per year. However, average

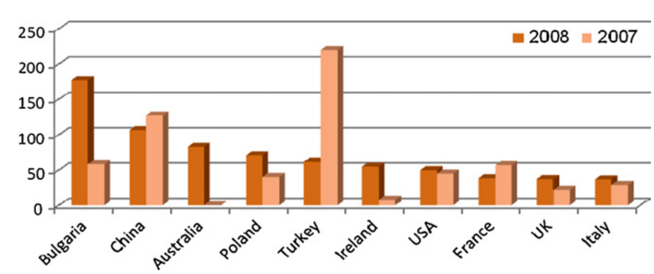


Fig. 2. Top 10 countries with highest growth rate [30].

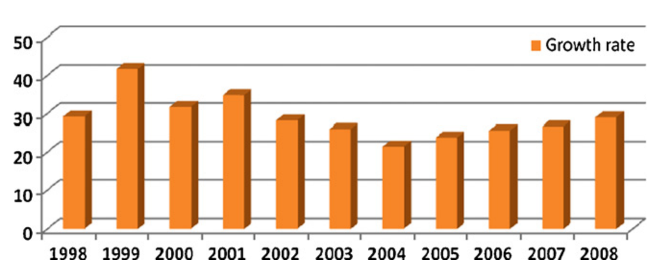


Fig. 3. World market growth rate in % [30].

prices remained rather stable since 1995. In fact, the price of the cheapest turbine available even increased during 1995–1999. There are a number of possible explanations for these trends. In Germany, more and more wind parks are situated in inland areas with lower wind speeds, due to a lack of appropriate sites near the coast. While in 1993, 70% of all new wind parks (in terms of capacity) were installed in coastal regions, this share has dropped to a mere 10–15% in 1999 [36,37]. The wind energy sector is one of the fastest-growing energy sectors in the world. From 1991 until the end of 2002, global installed capacity has increased from about 2 GW [38] to over 31 GW [39], with an average annual growth rate of about 26%. During this period, both prices of wind turbines and cost of wind-generated electricity have been reduced. In spite of these developments, electricity derived from wind is not yet able to fully compete with electricity produced from fossil fuel. However, this may change in the near future [36,40].

In terms of countries, the 'big five' (Germany, Spain, Denmark, the USA and India) have been at the top for the last decade (from 1995 to 2005). In these countries over 80% of the worldwide wind-based power generation capacity was installed in 2005 [36,39]. The expansion of renewable energies requires additional investments into production facilities as well as into the transportation and distribution grid. Since the majority of renewable energy technologies is not profitable at current energy prices, its furtherance is not only associated with production and employment effects but with increasing cost as well. It is apparent that the cost disadvantage of renewable compared to conventional energies is crucially dependent on future prices of energies used in power plants as well as on the amount of CO_2 emission permits [62,63].

4. Installed wind turbines worldwide (2007–2008)

The share of new installed capacity for USA and China with 31.62% and 23.83%, respectively accounts for more than half of the other countries in the world for 2008 (Fig. 4).

The USA and China took the lead, USA taking over the global number one position from Germany and China getting ahead of India for the first time, taking the lead in Asia. The USA and China accounted for 50.8% of the wind turbine sales in 2008 and the eight leading markets represented almost 80% of the market for new wind turbines. One year ago, still only five markets represented 80% of the global sales. The pioneer country Denmark fell back to rank 9 in terms of total capacity, while until four years ago it held the number 4 position during several years (Fig. 5). However, with a wind power share of around 20% of the electricity supply, Denmark is still a leading wind energy country worldwide [30]. For the year 2008, USA was in top position following by Germany, Spain, China, India, Italy, France, UK, Denmark and Portugal. But Germany was in top position in 2007.

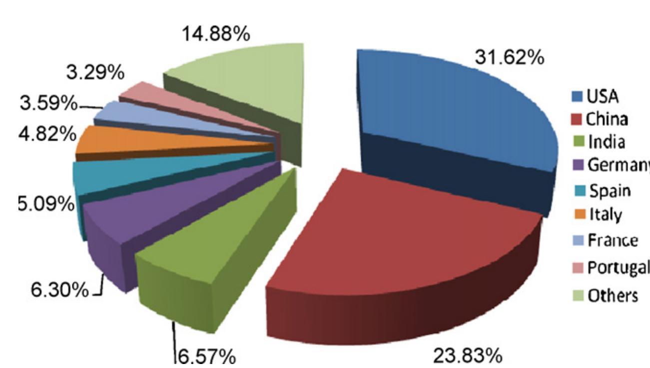


Fig. 4. Share of countries new installed capacity for 2008 [30].

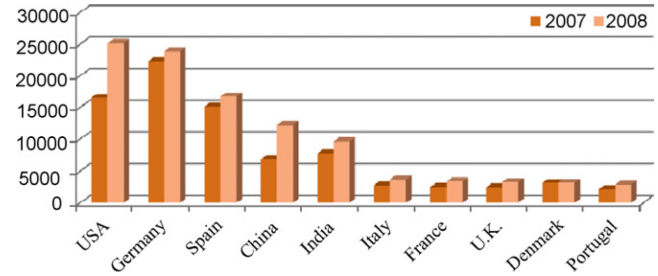


Fig. 5. Top 10 wind turbine installed countries (MW) [30].

5. World installation of wind turbines for 2006

The global wind energy market experienced yet another record year in 2006, demonstrating a growth of 32% over 2005 figures. According to the statistics (Table 2) issued by the Global Wind Energy Council (GWEC), 2006 saw the installation of 15,197 megawatt (MW) of new capacity, taking total installed wind energy capacity to 74,223 MW. In terms of economic value, the wind energy sector is now established as an important player in the energy market, the GWEC says. The total value of new generating equipment installed in 2006 was worth €18 billion (US$23 billion). The countries with the highest total installed capacity are Germany (20,621 MW), Spain (11,615 MW), the USA (11,603 MW), India (6270 MW) and Denmark (3136 MW). Thirteen countries around the world have now passed 1000 MW level for installed capacity. In terms of new capacity added in 2006, the USA led the way with 2454 MW, followed by Germany (2233 MW), India (1840 MW), Spain (1587 MW), China (1347 MW) and France (810 MW). These figures show that new players such as China and France are gaining ground [41]. By the end of 2006, cumulative installed wind capacity of China had reached 2.6 GW; the average annual growth rate over the past 10 years has been 46%. Between 2004 and 2006, China's ranking in the world wind energy league moved up from the top 10 to the top 6, and the country is planning to host some of the biggest wind farms in the world. At the present growth rate, the 2010 target will be reached 2 years earlier. Wind power has not just contributed to supplying electricity but has lowered supply costs, reduced carbon emissions and helped to limit air pollution [42].

5.1. Europe

Europe was the leading player in the market, with 48,545 MW of installed capacity at the end of 2006—65% of the global total. In 2006, European wind capacity grew by 19%, producing approximately 100 TWh of electricity, equal to 3.3% of total European Union (EU) electricity consumption in an average wind year. "While Germany and Spain still represented 50% of the EU market, there was healthy trend towards less reliance on these two countries, "says Christian Kjaer, the European Wind Energy Association's (EWEA) CEO". In the EU, 3755 MW was installed outside of Germany, Spain and Denmark in 2006. In 2002, this figure still stood at only 680 MW [41]. The figures show that most of the European countries were serious about investing into wind market.

Table 2
Installed capacity of top countries for January–December 2006 [41].

New capacity	MW	Market share (%)
USA	2,454	16.1
Germany	2,233	14.7
India	1,840	12.1
Spain	1,587	10.4
China	1,347	8.9
France	810	5.3
Canada	776	5.1
Portugal	694	4.6
UK	634	4.2
Italy	417	2.7
Top 10 total	12,792	84.2
Rest of world	2405	15.8
World total	15,197	

Following the agreement reached in March 2008 by the Heads of State [43], the European Union has committed itself to achieving, by 2020, that 20% of the energy it consumes comes from renewable energies and that its CO_2 emissions are cut by 20% in comparison with 1990 levels (30% if other developed countries join the effort) [44]. Wind is the most dynamic renewable energy in Europe and in the world; it already covers 3% of electricity demand in the EU—up to 23% in Denmark and around 8% in Spain and Germany [45] and is the second largest attractor of energy investments after natural gas [44,46]. Germany with total amount of 20,622 MW, Spain with 11,615 MW and Denmark with 3136 MW installed wind power capacity were in top positions in Europe. It shows that there was a tremendous need for renewable energies like wind in order to combat high price of fossil fuel. Europe with 48,545 MW of installed wind power capacity in 2006 was in top position which is admirable.

5.2. Asia

Asia experienced the strongest increase in installed capacity outside of Europe, with an addition of 3679 MW. This took the continent's total to over 10,600 MW. In 2006, wind capacity in Asia grew by 53% and accounted for 24% of new installations. The strongest market remains India, which installed over 1840 MW of new capacity in 2006, increasing its total to 6270 MW. China more than doubled its total installed capacity in 2006, taking it up to 2604 MW by installing 1347 MW of capacity, making it the sixth largest market worldwide. The Chinese market was boosted by the country's new Renewable Energy Law, which entered into force on 1 January 2006 [41].

In 2006, the burning of coal produced two-thirds of the primary energy consumed in China. Even with improvements in end-use energy efficiency, energy demand continues to grow and so does the air pollution. In China, pollution is causing serious health problems; crop damage and acid rain, all of which are taking a social and economic toll [42]. Air pollution has been a very serious problem in China, therefore government has implemented new regulations toward using renewable energies in order to decrease CO_2. They plan to have 5000 MW of wind energy by the year 2010. India with total amount of 6270 MW, China with 2604 MW and Japan with 1394 MW installed wind power capacity were in top positions in Asia. It shows that there was a great effort and attention in these countries toward using wind energy. The reason might be high cost of fossil fuel which was imported from Persian Gulf countries.

5.3. North America

North America accounted for 22% of the world's new installed wind capacity in 2006. For the second year running, the US wind energy industry installed nearly 2500 MW, making it the country with the most new wind power. "Wind's exponential growth reflects the nation's increasing demand for clean, safe and domestic energy, and continues to attract both private and public sources of capital," comments Randy Swisher, president of the American Wind Energy Association (AWEA). "New generating capacity worth US $4 billion was installed in 2006, billing wind as one of the largest sources of new power generation in the country—

second only to natural gas—for the second year in a row." Canada also had a record year, with the installed capacity more than doubling from 683 MW in 2005 to 1459 MW at the end of 2006. "Wind energy is an emerging Canadian success story and 2006 will be remembered as the year that our country first began to seriously capture its economic and environmental benefits," according to Robert Hornung, president of the Canadian Wind Energy Association (CanWEA). "Canada's on the cusp of a wind energy boom as provincial governments are now targeting to have a minimum of 10,000 MW of installed wind energy capacity in place by 2015" [41]. USA with total amount of 11,603 MW and Canada with 1459 MW installed wind power capacity were only countries in North America.

5.4. Latin America and Caribbean

Brazil with total amount of 237 MW, Mexico with 88 MW and Costa Rica with 74 MW installed wind power capacity were in top positions in Latin America and Caribbean. It shows that there was not tendency for wind turbine installation in this part of the world. Reason could be high resources of fossil fuel in countries like Mexico and also great attention toward manufacturing of methanol in Brazil.

5.5. Rest of the world

According to Table 3, growth in the relatively young African and Middle Eastern market picked up considerably in 2006, with 172 MW of new installed capacity, bringing the total up to 441 MW. This represents a 63% growth. The main countries experiencing increases are Egypt, Morocco and Iran. Compared to previous years, the Australian market only experienced slow growth in 2006 [41]. Egypt with total amount of 230 MW, Morocco with 124 MW and Iran with 48 MW installed wind power capacity were in top positions in Africa and Middle East. It shows that there was not too much attention in other countries in theses regions toward using wind energy. Australia with total amount of 817 MW, New Zealand with 171 MW and Pacific Island with 12 MW installed wind power capacity were in top positions in Pacific Region. Australia has been active in field of wind energy.

6. World installation of wind turbines for 2008

In terms of continental distribution, a continuous diversification process can be watched as well: in general, the focus of the wind sector moves away from Europe to Asia and North America. Europe (Fig. 6) decreased its share in total installed capacity from 65.5% in 2006 to 61% in the year 2007 further down to 54.6% in 2008. Only four years ago Europe dominated the world market with 70.7% of the new capacity. In 2008 the continent lost this position and, for the first time, Europe (32.8%), North America (32.6%) and Asia (31.5%) account for almost similar shares in new capacity. However, Europe is still the strongest continent while North America and Asia are increasing rapidly their shares. The countries in Latin America and Africa counted for respectively only 0.6% and 0.5% of the total capacity and fell back in terms of new installations down to respectively only 0.4% and 0.3% of the additional capacity installed worldwide in the year 2008 [30]. Wind energy generating capacity in the US increased from about 2500 MW in 1999 to about 21,000 MW in mid 2008 and about 28,000 MW in early 2009. At the same time, the costs of installed utility-scale wind projects (in constant $/kW) declined until the early 2000s and then generally increased [21,47,48]. Mass production is likely to play a significant role for future cost

Table 3
Global installed wind power capacity (MW)-regional distribution [41].

Country	Total end 2005	New 2006	Total end 2006
Africa and middle east			
Egypt	145	85	230
Morocco	64	60	124
Iran	23	27	48
Tunisia	20	0	20
Other	11	0	11
Total	271	172	441
Asia			
India	4,430	1,840	6,270
China	1,260	1,347	2,604
Japan	1,061	333	1,394
Taiwan	104	84	188
South Korea	98	75	173
Philippines	25	0	25
Other	13	0	13
Total	6,990	3,679	10,667
Europe			
Germany	18,415	2,233	20,622
Spain	10,028	1,587	11,615
Denmark	3,128	12	3,136
Italy	1,718	417	2,123
UK	1,332	634	1,963
Portugal	1,022	694	1,716
France	757	810	1,567
Netherland	1,219	356	1,560
Austria	819	146	965
Greece	573	173	746
Ireland	496	250	745
Sweden	510	62	572
Norway	267	47	314
Belgium	167	26	193
Poland	83	69	153
Rest of Europe	364	192	556
Total Europe	40,898	7,708	48,545
Out of which UE-27	40,512	7,611	48,062
Latin America and Caribbean			
Brazil	29	208	237
Mexico	3	85	88
Costa Rica	71	3	74
Caribbean (w/o Jamaica)	35	–	35
Argentina	27	–	27
Colombia	20	–	20
Jamaica	20	–	20
Other	7	–	7
Total	212	296	508
North America			
USA	9,149	2,454	11,603
Canada	683	776	1,459
Total	9,832	3,230	13,062
Pacific region			
Australia	708	109	817
New Zealand	169	3	171
Pacific island	12	–	12
Total	889	112	1,000
Word total	59,091	15,197	74,223

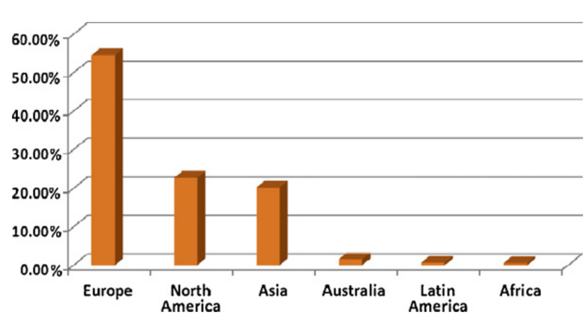


Fig. 6. Continental share of total installed capacity 2008 [30].

reductions. In the last 5 years, wind farms of several hundred MW capacities have been realized in Spain and the USA [36]. Since the majority of renewable energy technologies are not profitable at current energy prices, its furtherance is not only associated with production and employment effects but with increasing cost as well. It is apparent that the cost disadvantage of renewable compared to conventional energies is crucially dependent on future prices of energies used in power plants as well as on the amount of CO_2 emission permits [19,20]. Australian share in these regards is more than share of both Latin America and Africa.

6.1. Europe

Europe lost its dominating role as new market but kept its leading position in terms of total installation with 66,160 MW. Germany and Spain maintained as leading markets, both showing stable growth. The most dynamic European markets were Ireland (adding 440 MW, 55% growth) and Poland (196 MW added, 71% growth), the first Eastern European country with a substantial wind deployment. All in all, the European wind sector showed almost stagnation with a very small increase in added capacity from 8607 to 8928 MW. The biggest market Germany is expected, after the amendment of the renewable energy law EEG, to show bigger market growth in 2009. An encouraging change happened in the UK where the government announced the introduction of a feed-in tariff for community based renewable energy projects. However, the cap of 5 MW represents a major hurdle so that the UK wind market will still grow at moderate rates. However, without additional incentives for wind power in more EU member states, such as improved feed-in legislation, the European Union may not be able to achieve its 2020 targets for renewable energy [30]. It goes without saying that most of the European countries were in top positions in 2008. Germany and Spain were in second and third position with total capacity installed of 23902.8 and 16740.3 MW, respectively. But Germany with 22247.4 MW and Spain with 15147.4 MW of total capacity installed for 2007 were in first and third positions. Italy, France, United Kingdom, Denmark and Portugal were in position of 6–10, respectively for 2008. It shows great effort of European countries toward using wind energy for electricity production. Recently, because of the global economic crisis, some wind turbine manufacturing companies in Europe dismissed the workers and decreased production lines in order to combat the crisis.

6.2. Asia

Asia with the two leading wind countries China and India and 24,439 MW of installed capacity is in a position of becoming the worldwide locomotive for the wind industry. China has again doubled its installations and Chinese domestic wind turbine manufacturers have started for the first time to export their products. It can be expected that in the foreseeable future Chinese and Indian wind turbine manufacturers will be among the international top suppliers.

The Indian market has shown robust and stable growth in the year 2008. It has already a well-established wind industry which already plays a significant and increasing role on the world markets. Further countries like South Korea (already with 45% growth rate in 2008) start investing on a larger scale in wind energy and it can be observed that more and more companies are developing wind turbines and installing first prototypes. In parallel with the market growth in the country, it can be expected that also new manufacturers will be able to establish themselves. The World Wind Energy Conference held on Jeju Island in June 2009 is expected to push the development in the region. Pakistan installed its first wind farm in the year 2008 and the Government of the country aims at further wind farms in the near future [30]. China has chosen wind power as an important alternative source in order to rebalance the energy mix, combat global warming and ensure energy security. Supportive measures have been introduced. In order to encourage technical innovation, market expansion and commercialization, development targets have been established for 2010 and 2020, concession projects offered and policies Introduced to encourage domestic production [42].

China with 12210.0 MW and India with 9587.0 MW of total capacity installed in 2008 were in positions of fourth and fifth in the world. Japan, South Korea and Iran with total installed capacities of 1880.0, 278 and 823 MW, respectively were in positions of 13, 27 and 35 in the world for 2008 (Table 3). The positions of Japan and South Korea for year 2007 were same as 2008, but Iran had position of 34 in 2007. Philippine, Israel, Pakistan, Jordan, Indonesia, Mongolia, Kazakhstan, Syria and South Korea were among the Asian countries with wind turbine activities in 2008.

6.3. North America

North America showed very strong growth in the year 2008, more than doubling its capacity since 2006 to 27,539 MW. Breaking two world records, the USA became the new number one worldwide in terms of added as well as in terms of total capacity. More and more US states are establishing favorable legal frameworks for wind energy and try to attract investors in manufacturing facilities. It can be expected that the new President Obama administration will improve substantially the political frameworks for wind power in the country, especially for those types of investors that have practically been excluded from the production tax credit scheme, like farmers, smaller companies or community based projects. The credit crunch, however, may lead to delays in project development in the short term. The Canadian government has rather been hesitating. However, among the Canadian provinces Quebec and Ontario are showing increasing commitment towards an accelerated deployment of wind energy. In Quebec, contracts for new projects were signed for a total of 2000 MW, the first to be operational by 2011 [30]. USA with total installed capacity of 25,170 MW and Canada with 2369 MW in 2008 were in positions of 1st and 11th in the world. But for the year 2007, USA was in position of 2nd and Canada in position of 11th.

6.4. Latin America

Many Latin American markets still showed stagnation in the year 2008 and the overall installed capacity (667 MW) in the region accounts for only 0.5% of the global capacity. Only Brazil and Uruguay installed major wind farms in the year 2008. This slow wind deployment is especially dangerous for the economic and social prospects of the region as in many countries people are already suffering from power shortages and sometimes do not have access to modern energy services at all. However, in some countries like Argentina, Brazil, Chile, Costa Rica or Mexico many projects are under construction thus putting lights in the forecast for 2009 [30]. Brazil with 338.5 MW and Mexico with 85.0 MW of total capacity installed in 2008 were in positions of 24th and 34th in the world. Costa Rica, Argentina, Uruguay and Chile with total installed capacities of 74.0, 29.8, 20.5 and 20.1 MW, respectively were in positions of 37, 41, 46 and 47 in the world for 2008 (Table 4).

6.5. Africa

In spite of the huge potentials all over the continent, with world's best sites in the North and South of the continent, wind

Table 4
Total capacity installed and position of countries [30].

Position 2008	Country	Total capacity installed end 2008 [MW]	Added capacity 2008 [MW]	Growth rate 2008 [%]	Position 2007	Total capacity installed end 2007 [MW]	Total capacity installed end 2006 [MW]	Total capacity installed end 2005 [MW]
1	USA	25170.0	8351.2	49.7	2	16818.8	11603.0	9149.0
2	Germany	23902.8	1655.4	7.4	1	22247.4	20622.0	18427.5
3	Spain	16740.3	1595.2	10.5	3	15147.4	11630.0	10027.9
4	China	12210.0	6298.0	106.5	5	5912.0	2599.0	1266.0
5	India	9587.0	1737.0	22.1	4	7850.0	6270.0	4430.0
6	Italy	3736.0	1009.9	37.0	7	2726.1	2123.0	1718.0
7	France	3404.0	949.0	38.7	8	2455.0	1567.0	757.2
8	United Kingdom	3287.9	898.9	37.6	9	2389.0	2123.4	1353.0
9	Denmark	3160.0	35.0	1.1	6	3125.0	1567.0	3128.0
10	Portugal	2862.0	732.0	34.4	10	2130.0	1962.0	1022.0
11	Canada	2369.0	523.0	28.3	11	1846.0	3136.0	638.0
12	The Netherlands	2225.0	478.0	27.4	12	1747.0	1716.0	1224.0
13	Japan	1880.0	352.0	23.0	13	1528.0	1460.0	1040.0
14	Australia	1494.0	676.7	82.8	16	817.3	1559.0	579.0
15	Ireland	1244.7	439.7	54.6	17	805.0	1309.0	495.0
16	Sweden	1066.9	235.9	28.4	18	831.0	817.3	509.0
17	Austria	994.9	13.4	1.4	14	981.5	746.0	819.0
18	Greece	989.7	116.5	13.3	15	873.3	964.5	573.3
19	Poland	472.0	196.0	71.0	24	276.0	757.6	73.0
20	Norway	428.0	95.1	28.5	19	333.0	153.0	268.0
21	Egypt	390.0	80.0	25.8	21	310.0	230.0	145.0
22	Belgium	383.6	78.3	33.7	22	286.9	194.3	167.4
23	Chinese Taipei	358.2	96.7	28.0	23	297.9	187.7	103.7
24	Brazil	338.5	91.5	37.0	25	247.1	236.9	28.6
25	Turkey	333.4	126.6	61.2	26	206.8	64.6	20.1
26	New Zealand	325.3	3.5	1.1	20	321.8	171.0	168.2
27	Korea (south)	278.0	85.9	44.7	27	192.1	176.3	119.1
28	Bulgaria	157.5	100.6	176.7	33	56.9	36.0	14.0
29	Czech Republic	150.0	34.0	29.3	28	116.0	56.5	29.5
30	Finland	140.0	30.0	30.3	29	110.0	86.0	82.0
31	Hungary	127.0	62.0	95.4	35	65.0	60.9	17.5
32	Morocco	125.2	0.0	0.0	36	125.2	64.0	64.0
33	Ukraine	90.0	1.0	1.1	30	89.0	85.6	77.3
34	Mexico	85.0	0.0	0.0	31	85.0	84.0	2.2
35	Iran	823.0	15.5	23.3	34	66.5	47.4	31.6
36	Estonia	78.3	19.7	33.6	37	58.6	33.0	33.0
37	Costa Rica	74.0	0.0	0.0	32	74.0	74.0	71.0
38	Lithuania	54.4	2.1	4.0	38	52.3	55.0	7.0
39	Luxembourg	35.3	0.0	0.0	39	35.3	35.3	35.3
40	Latvia	30.0	2.6	9.5	41	27.4	27.4	27.4
41	Argentina	29.8	0.0	0.0	40	27.8	27.8	27.8
42	Philippines	25.2	0.0	0.0	42	25.2	25.2	25.2
43	South Africa	21.8	5.2	31.4	49	16.6	16.6	16.6
44	Jamaica	20.7	0.0	0.0	43	20.7	20.7	20.7
45	Guadeloupe	20.5	0.0	0.0	44	20.5	20.5	20.5
46	Uruguay	20.5	19.9	3308.3	68	0.6	0.2	
47	Chile	20.1	0.0	0.0	46	20.1	2.0	2.0
48	Tunisia	20.0	0.0	0.0	45	20.0	20.0	20.0
49	Colombia	19.5	0.0	0.0	47	19.5	19.5	19.5
50	Croatia	18.2	1.0	5.8	48	17.2	17.2	6.0
51	Russia	16.5	0.0	0.0	50	16.5	15.5	14.0
52	Switzerland	13.8	2.2	19.2	53	11.6	11.6	11.6
53	Guyana	13.5	0.0	0.0	51	13.5	13.5	13.5
54	Curacao	12.0	0.0	0.0	52	12.0	12.0	12.0
55	Romania	7.8	0.0	0.0	54	7.8	2.8	0.9
56	Israel	6.0	0.0	0.0	55	6.0	7.0	7.0
57	Pakistan	6.0	0.0	New	New	0.0	0.0	0.0
58	Slovakia	5.1	6.0	2.8	56	0.5	5.0	5.0
59	Faroe Islands	4.1	0.1	0.0	57	4.1	4.1	4.1
60	Ecuador	4.0	0.9	3.7	58	3.1	0.0	0.0
61	Cuba	3.2	5.1	242.9	61	2.1	0.5	0.5
62	Cape Verde	2.8	0.0	0.0	59	2.8	2.8	2.8
63	Mongolia	2.4	2.4	New	New	0.0	0.0	0.0
64	Nigeria	2.2	0.0	0.0	60	2.2	2.2	2.2
65	Jordan	2.0	0.0	0.0	62	2.0	1.5	1.5
66	Indonesia	1.2	0.2	20.0	65	1.0	0.8	0.8
67	Martinique	1.1	0.0	0.0	63	1.1	1.1	1.1
68	Belarus	1.1	0.0	0.0	64	1.1	1.1	1.1
69	Eritrea	0.8	0.0	0.0	66	0.8	0.8	0.8
70	Peru	0.7	0.0	0.0	67	0.7	0.7	0.7
71	Kazakhstan	0.5	0.0	0.0	69	0.5	0.5	0.5
72	Namibia	0.5	0.0	6.4	70	0.3	0.3	0.3
73	Netherland Antilles	0.3	0.0	0.0	71	0.0	0.0	0.0
74	Syria	0.3	0.0	0.0	72	0.03	0.03	0.03

Table 4 (*Continued*)

Position 2008	Country	Total capacity installed end 2008 [MW]	Added capacity 2008 [MW]	Growth rate 2008 [%]	Position 2007	Total capacity installed end 2007 [MW]	Total capacity installed end 2006 [MW]	Total capacity installed end 2005 [MW]
75	North Korea	0.2	0.2	2010.0	73	0.01	0.01	0.01
76	Bolivia	0.01	0.0	0.0	74	0.0	0.0	0.0
Total		121187.9	27261.1	29.0		93926.8	74150.8	59024.1

energy plays still a marginal role on the continent with 563 MW of total capacity. Several major wind farms can be found in some of the North African countries like Morocco, Egypt or Tunisia. In the year 2009 and 2010, substantial increases can be expected from projects which are already in the development stage. However, so far, the emergence of domestic wind industry in African countries is only in a very early stage. However, it is interesting to see that companies from the region are showing an increasing interest and have started investing in the wind sector. In Sub-Saharan Africa, the installation of the first wind farm in South Africa operated by an Independent Power Producer can be seen as a major breakthrough. The South African government prepares the introduction of a feed-in tariff which would create a real market, enable independent operators to invest and thus play a key role in tackling the country's power crisis. In the mid-term, small, decentralized and stand-alone wind energy systems, in combination with other renewable energies, will be key technologies in rural electrification of huge parts of so far unserved areas of Africa [30]. Egypt with 390.0 MW and Morocco with 125.2 MW of total capacity installed in 2008 were in positions of 21st and 32nd in the world (Table 4). South Africa, Tunisia, Nigeria, Eritrea and Namibia with total installed capacities of 21.8, 20.0, 2.2, 0.8 and 0.5 MW, respectively were in positions of 43, 48, 64, 69 and 72 in the world for 2008.

6.6. Australia and Oceania

The region showed encouraging growth rates, reaching 1819 MW by the end of 2008, most of it thanks to Australia. Commitments made by the Australian government to increase their efforts in climate change mitigation and expansion of renewable energies create the expectation that the Australian wind energy market will show further robust growth also in the coming years. New Zealand, after a change in government, may, however, face major delay in its switch to renewable energy [30]. Australia with 1494 MW and New Zealand with 325.3 MW of total capacity installed in 2008 were in positions of 14th and 26th in the world. Australia was in position of 16th and New Zealand was in position of 20th for the year 2007.

7. Employment issues regarding wind energy

Wind energy is often said to have positive effects on employment, but few studies have systematically dealt with this matter [26]. The development of renewable energy industries and saving energy technologies became a way to achieve environmental objectives and a means of increasing energy self-sufficiency and employment [49,19,50–55]. The use of renewable energies offers the opportunity to diminish energy dependence, reduce the emission of CO_2 and create new employment. The involvement of local agents is highly important for the future development in this field, especially in regions whose industrial mix was based on traditional energy sources [49]. Wind industry in Europe is a predominantly male business with 78% employment, where men make up majority of the labor in fields of construction, production and engineering.

One fundamental advantage of wind energy is that it replaces expenditure on mostly imported fossil or nuclear energy resources by human capacities and labor. Wind energy utilization creates many more jobs than centralized, non-renewable energy sources. The wind sector (Fig. 7) worldwide has become a major job generator: within only three years, the wind sector worldwide almost doubled the number of jobs from 235,000 in 2005 to 440,000 in the year 2008. These 440,000 employees in the wind sector worldwide, most of them highly skilled jobs, are contributing to the generation of 260 TWh of electricity [30].

The wind energy sector has grown exponentially since the end of the 1990s, especially within the European Union (EU), and this has affected the employment levels of the regions involved [26]. The expansion of renewable energies requires additional investments into production facilities as well as into the transportation and distribution grid [19]. Unemployment rates around 10% shifted the focus of the analysis of the economic effects of the German Renewable Energy Sources Act (EEG) on labor market effects, and several studies have analyzed these effects [55–58]. These earlier studies either focused on the effects of electricity only, or modeled the end of the German feed-in tariff system and focus on the development until 2010 [59]. Wind energy represents an attractive source of employment in Europe. Since a number of activities (construction, O&M, legal and environmental studies) are best dealt with at local level, there will always be a positive corelation between the location of the wind farm and the number of jobs it creates. The decision of where to locate large manufacturing centers, however, seems to rely on other, often microeconomic factors, and this is where regional and municipal authorities have a role to play. Another relevant point is that wind energy employment is following the opposite trend to the general energy sector, particularly coal extraction and electricity generation, and measures that encourage the transfer of workers from general energy to wind energy will be highly beneficial from both social and economic point-of-view [26]. Manufacturers and component manufacturers (Fig. 8) with 37% and 22%, respectively make up the highest share of direct jobs in wind energy. Service companies are the third largest category, followed by project developers. Operation and Maintenance (O&M) with 11% is in next category.

The development of any new industry, including wind power, can create new domestic job opportunities, and wind development is often credited with creating more jobs per dollar invested and per kilowatt-hour generated than fossil fuel power generation [60]. Direct jobs are typically created in three areas: manufacturing of

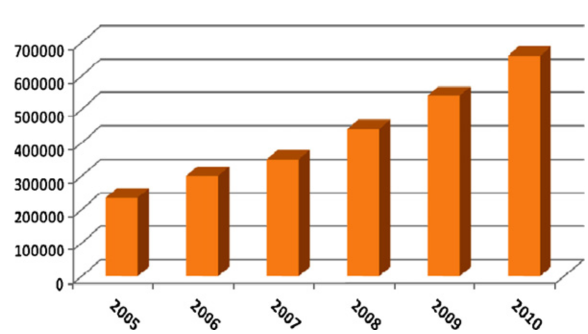


Fig. 7. Wind energy jobs worldwide [30].

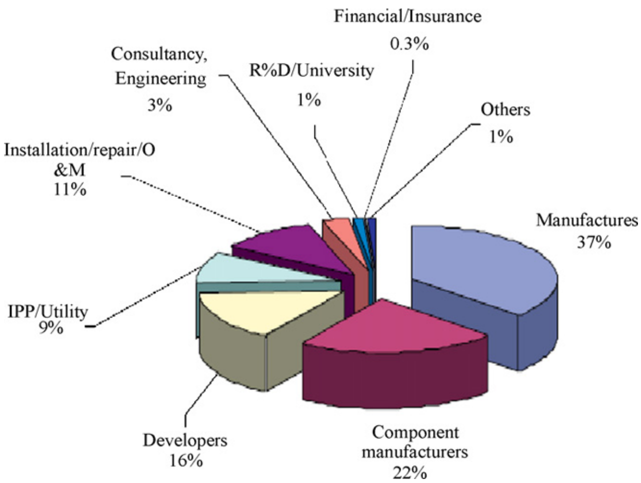


Fig. 8. Direct employment by type of company in EU [26].

Table 5
Summary of employment profiles (direct jobs) in different EU member states [26,19,50–54].

Country	No. of direct jobs
Austria	750
Belgium	2,000
Bulgaria	100
Czech	100
Denmark	17,000 (23,500)
Finland	800
France	6,000
Germany	38,000
Greece	1,800
Hungary	100
Ireland	1,500
Italy	3,000
Netherlands	2,000
Poland	800
Portugal	3,000
Spain	20,500
Sweden	2,000
UK	4,500
Rest of world	400

wind power equipment, constructing and installing the wind projects, and operating and maintaining the projects over their lifetime [25].

In addition, there are limited global locales possessing a skilled labor force in wind power, with Denmark still representing a unique hub of skilled laborers and an experienced network of key components suppliers to support turbine manufacturers. Suzlon recently decided to base its international headquarters in Denmark to take advantage of this knowledge base, even though it has stated that it is unlikely to sell its turbines to the Danish market [25,61]. Wind energy companies in the EU employed around 104,350 people in 2008. This represents a growth of 226% with respect to 2003 [26]. Germany with total no. of 38,000 persons employed directly in wind industry is leader in Europe (Table 5). Spain and Denmark are also countries with high employment rates in wind energy business too.

8. Conclusion

Renewable energy sources have been facing a growing attention in global energy markets due to many benefits associated with their importance. During past few years, a great attention was paid toward using wind energy in many countries around the world, USA, Germany, India and China were among the countries which were more successful in order to install wind turbines in recent years. It should be noted that other countries like Bulgaria and Turkey had the highest growth rate for 2008 and 2007, respectively. In general, the focus of the wind sector moves away from Europe to Asia and North America. Europe decreased its share in total installed capacity from 65.5% in 2006 to 61% in the year 2007 further down to 54.6% in 2008. Only four years ago Europe dominated the world market with 70.7% of the new capacity. In 2008 the continent lost this position and, for the first time, Europe (32.8%), North America (32.6%) and Asia (31.5%) account for almost similar shares in new capacity. Europe lost its dominating role as new market but kept its leading position in terms of total installation with 66,160 MW. Asia with the two leading wind countries China and India and 24,439 MW of installed capacity is in a position of becoming the worldwide locomotive for the wind industry. In spite of the huge potentials all over the Africa, with world's best sites in the North and South of the continent, wind energy plays still a marginal role on the continent with 563 MW of total capacity. Australia showed encouraging growth rates, reaching 1819 MW by the end of 2008. Many Latin American markets still showed stagnation in the year 2008 and the overall installed capacity (667 MW) in the region accounts for only 0.5% of the global capacity. North America showed very strong growth in the year 2008, more than doubling its capacity since 2006 to 27,539 MW. The wind sector worldwide has become a major job generator. Within only three years, the wind sector worldwide almost doubled the number of jobs from 235,000 in 2005 to 440,000 in the year 2008. Wind energy represents an attractive source of employment in many countries in the world. There are some activities like operation and maintenance (O&M), research and development (O&M), manufacturing and construction which are able to create jobs in wind industries.

References

[1] Held A, Faber T, Panzer C, Toro F, Haas R, Resch G. Potentials and prospects for renewable energies at global scale. Energy Policy 2008;36:4048–56.
[2] Ozer S, Tosun M. Feasibility study of wind farms: a case study for Izmir, Turkey Baris Ozerdem. Journal of Wind Engineering and Industrial Aerodynamics 2006;94:725–43.
[3] Usha Rao K, Kishore VVN. Wind power technology diffusion analysis in selected states of India. Renewable Energy 2009;34:983–8.
[4] Pullen A. Global wind 2005 report. Global Wind Energy Council; 2005 . pp. 1–50, www.gwec.net.
[5] Breton SP, Moe G. Status, plans and technologies for offshore wind turbines in Europe and North America. Renewable Energy 2009;34:646–54.
[6] National Wind Energy Coordinating Committee. Permitting wind energy facilities—a handbook. NWCC Siting Subcommittee; March 1998, www.nationalwind.org.
[7] Honnery D, Moriarty P. Estimating global hydrogen production from wind. International Journal of Hydrogen Energy 2009;34:727–36.
[8] De Vries BJ, Van Vuuren D, Hoogwijk MM. Renewable energy sources: their potential for the first half of the 21st century at a global level: an integrated approach. Energy Policy 2007;35:2590–610.
[9] Moriarty P, Honnery D.In: Can renewable energy avert global climate change? International clean air conference; 2005.
[10] BTM Consult ApS. International Wind Energy Development, World Market Update 2004; March 2005.
[11] Intergovernmental Panel on Climate Change (IPCC). Climate change 2001: mitigation. Cambridge, UK: Cambridge University Press; 2001.
[12] Seyit A, Akdaga, Dinler A. A new method to estimate Weibull parameters for wind energy applications. Energy Conversion and Management 2009;50: 1761–6.
[13] World Wind Energy Association. Wind turbines generate more than 1% of the global electricity. http://www.wwindea.org, Press Release; February 2008.
[14] Carta JA, Ramírez P, Velázquez S. A review of wind speed probability distributions used in wind energy analysis. Renewable and Sustainable Energy Reviews 2009;13(5):933–55.
[15] Petersen LE. Wind power meteorology. Roskilde, Denmark: Risoe National Laboratory Press; 1997.
[16] Ohlhorst D, Bruns E, Schon S, Koppel J. Wind energie boomin Deutsch land. Peter Lang Publishing; 2008. pp. 5–60.
[17] Nitsch J. "Leitstudie 2008: Weiterentwicklung der "Ausbaustrategie Erneuerbare Energien" vor dem Hintergrund der aktuellen Klimaschutzziele Deutschlands und Europas". Berlin; 2008.
[18] Portman ME, Duff JA, Koppel J, Reisert J, Higgins ME. Offshore wind energy development in the exclusive economic zone: legal and policy supports and impediments in Germany and the US. Energy Policy 2009;37:3596–607.

[19] Hillebrand B, Buttermann HG, Behringer JM, Bleuel M. The expansion of renewable energies and employment effects in Germany. Energy Policy 2006;34:3484–94.
[20] European Parliament. Directive 2004/101/EC of the European Parliament and the Council of 27 October 2004 amending directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community, in respect of the Kyoto Protocol's project mechanisms. L 338/18. Brussels; 2004.
[21] Berry D. Innovation and the price of wind energy in the US. Energy Policy 2009. doi: 10.1016/j.enpol.2009.05.071.
[22] Thresher R, Robinson M, Veers P. Wind energy technology: current status and R&D future. Golden, CO: National Renewable Energy Laboratory; 2008[NREL/CP-500-43374].
[23] International Energy Agency (IEA). Wind energy annual report 2003. www.ieawind.org/iea; 2004.
[24] Zhao ZU, Hua J, Zuo J. Performance of wind power industry development in China: a Diamond Model study. Renewable Energy 2009;34:2883–91.
[25] Lewisa JI, Wiserb RH. Fostering a renewable energy technology industry: an international comparison of wind industry policy support mechanisms. Energy Policy 2007;35:1844–57.
[26] Blanco MI, Rodriguez G. Direct employment in the wind energy sector: an EU study. Energy Policy 2009;37:2847–57.
[27] Global wind energy outlook 2008. Green Peace International, DLR and Ecofys; October, 2008.
[28] Investing in Renewable Technologies: Wind, solar, geothermal, hydro, biomass. Renewable Energy Reports www.energybusinessreports.com; 9 September 2009.
[29] The 8th World Wind Energy Conference 2009 (WWEC2009) on Jeju island/South Korea the World Wind Energy Association (WWEA); 2009.
[30] World Wind Energy Association (WWEA); 2008.
[31] Cavaliero C, DaSilva E. Electricity generation: regulatory mechanisms to incentive renewable alternative energy sources in Brazil. Energy Policy 2005;33:1745–52.
[32] Lew D. Alternatives to coal and candles: wind power in China. Energy Policy 2000;28:271–86.
[33] Rogner HH. Energy resources. In: World energy assessment—2004 update. United Nations Development Programme, United Nations Department of Economic and Social Affairs, World Energy Council; 2004 [chapter 5].
[34] Grubb M, Meyer N. Resources, systems and regional strategies. In: Renewable Energy. Sources for fuels and electricity. Washington, DC: Island Press, Wind energy; 1993. pp. 157–212.
[35] Haefele W. Energy in a finite world a global systems analysis Report by the Energy Systems Group of the International Institute for Applied Systems Analysis, vol. 2. Cambridge, MA: Ballinger Publishing Company; 1981.
[36] Junginger M, Faaij A, Turkenburg WC. Global experience curves for wind farms. Energy Policy 2005;33:133–50.
[37] Durstewitz M, Hoppe-Kilpper M. Bericht zur Markt-und Kosten entwicklung bei Windenergie anlagen. Kassel: Institut fur Solare Energie versorgungs technik e.V. (ISET); 2002.
[38] EWEA (European Wind Energy Association). Wind Energy: The Facts. London; 1997.
[39] Milborrow D, Tishler C, Harrison L, O'Bryant M. The windicator. Wind Power Monthly)2003;(April).
[40] Turkenburg WC, Beurskens J, Faaij A, Fraenkel P, Fridleifsson I, Lysen E, et al. In: Goldemberg J, editor. World energy assessment. Chapter 7: renewable energy technologies. Washington, DC: World Energy Assessment, UND; 2000 p. 220–72.
[41] Global Wind Energy Council (GWEC). www.gwec.net; April 2007.
[42] China Renewable Energy Market Outlook. http://www.energybusinessreports.com; May 2008.
[43] Council of the European Union, 7224/1/07 Rev: Brussels European Council, 8–9 March 2007. Presidency Conclusions. <www.consilium.europa.eu>; 2007.
[44] Blanco MI, Rodriguez G. Can the future EU ETS support wind energy investments? Energy Policy 2008;36:1509–20.
[45] European Wind Energy Association (EWEA). Wind Map in Europe, 2006. www.ewea.org; 2007.
[46] Platts. Platts Power Vision; March 2007.
[47] Lemming J. Cost reduction potentials in wind. Presentation at the IEA Technology Learning and Deployment Workshop, Paris; 2007.
[48] Wiser R, Bolinger M. Annual report on US wind power installation, cost, and performance trends: 2007. Energy Efficiency and Renewable Energy. Washington, DC: US Department of Energy; 2008.
[49] Moreno B, Lopez AJ. The effect of renewable energy on employment. The case of Asturias (Spain). Renewable and Sustainable Energy Reviews 2008;12:732–51.
[50] Connor PM. UK renewable energy policy: a review. Renewable and Sustainable Energy Reviews 2003;7:65–82.
[51] Dincer I. Renewable energy and sustainable development: a crucial review. Renewable and Sustainable Energy Reviews 2000;4:157–75.
[52] Laitner S, Bernow B, Cicco JD. Employment and other macroeconomic benefits of an innovation-led climate strategy for the United States. Energy Policy 1998;26:425–32.
[53] Lenzen M, Dey CJ. Economic, energy and greenhouse emissions impacts of some consumer choice, technology and government outlay options. Energy Economic 2002;24:377–403.
[54] Thothathri R. The wind brought jobs and prosperity. New Energy 1999;4:28–30.
[55] Pfaffenberger W. Wertschö pfung und Beschä ftigung durch grü ne Energieproduktion? Energiewirtschaftliche Tagesfragen 2006;22–6.
[56] Pfaffenberger W, Nguyen K, Gabriel J. Ermittlung der Arbeitsplä tze und Beschä ftigungswirkungen im Bereich erneuerbarer Energien. Studie des bremer energie instituts im Auftrag der Hans-Böckler-Stiftung; 2003.
[57] Hillebrand B, Buttermann HG, Behringer JM, Bleuel M. The expansion of renewable energies and employment effects in Germany. Energy Policy 2006;34(18):3484–94.
[58] Fahl U, Kuster R, Ellersdorfer I. Jobmotor Ökostrom? Beschäftigungseffekte der Förderung von erneuerbaren Energien in Deutschland. Energiewirtschaftliche Tagesfragen 2005;55(7):476–81.
[59] Lehr U, Nitsch J, Kratzat M, Lutz C, Edler D. Renewable energy and employment in Germany. Energy Policy 2008;36:108–17.
[60] Singh V, Fehrs J. The Work that Goes into Renewable Energy. Renewable Energy Policy Project Research Report 14, November 2001.
[61] Wind power Monthly (WPM). Denmark picked for global headquarters. Wind Power Monthly News Magazine A/S, Denmark; October 2004:25.
[62] Stern N. The economics of climate change. American Economic Review 2008;98(2):1–37.
[63] The carbon productivity challenge. McKinsey Global Institute; 2008.